

The EOS Aura Mission

The Earth Observing System Missions and Aura

The Earth Observing System (EOS) Aura satellite is scheduled to launch in the second quarter of 2004. The Aura mission is designed to attack three science questions: (1) Is the ozone layer recovering as expected? (2) What are the sources and processes that control tropospheric pollutants? (3) What is the quantitative impact of constituents on climate change? Aura will answer these questions by globally measuring a comprehensive set of trace gases and aerosols (Table 1) at high vertical and horizontal resolution. Fig. 1 shows the Aura spacecraft and its four instruments.

The EOS Program consists of three core satellites, Terra (<http://eos-am.gsfc.nasa.gov/>), Aqua (<http://eos-pm.gsfc.nasa.gov/>) and Aura (<http://eos-aura.gsfc.nasa.gov/>) as well as several smaller satellites. Aura (Latin for breeze, formerly CHEM) will be launched into an ascending node 705 km sun-synchronous polar orbit with a 98° inclination with an equator-crossing time of 13:45±15 minutes. The design life is five years with an operational goal of six years. Aura will fly in formation about 15 minutes behind Aqua, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO, <http://www-calipso.larc.nasa.gov/>) and Cloudsat to be launched together in 2005 [Stephens et al., 2002, <http://cloudsat.atmos.colostate.edu/>]. This group of satellites, including the CNES PARASOL satellite (http://smc.cnes.fr/PARASOL/GP_mission.htm) and the ESSP Orbiting Carbon Observatory (OCO, <http://oco.jpl.nasa.gov/>), is referred to as the "A-Train." The measurements from Aura will be within 30 minutes of these other platforms.



Figure 1, Computer model of the Aura spacecraft showing the location of HIRDLS, MLS, OMI and TES. See Table 1. (Graphic by Jesse Allen, NASA Earth Observatory)

TABLE 1 – Aura Instruments, Principle Investigators and Measurements

Acronym	Name	Instrument PI	Constituent	Instrument Description
HIRDLS	High Resolution Dynamics Limb Sounder	John Gille, National Center for Atmospheric Research & U. of Colorado; John Barnett, Oxford University	Profiles of T, O ₃ , H ₂ O, CH ₄ , N ₂ O, NO ₂ , HNO ₃ , N ₂ O ₅ , CF ₃ Cl, CF ₂ Cl ₂ , ClONO ₂ , Aerosols	Limb IR filter radiometer from 6.2μ to 17.76μ 1.2 km vertical resolution up to 80 km.
MLS	Microwave Limb Sounder	Joe Waters, Jet Propulsion Laboratory	Profiles of T, H ₂ O, O ₃ , ClO, BrO, HCl, OH, HO ₂ , HNO ₃ , HCN, N ₂ O, CO, Cloud ice.	Microwave limb sounder 118 GHz to 2.5 THz 1.5-3 km vertical resolution
OMI	Ozone Monitoring Instrument	Pieter Levelt, KNMI, Netherlands	Column O ₃ , SO ₂ , aerosols, NO ₂ , BrO, OCIO, HCHO, UV-B, cloud top pressure, O ₃ profiles.	Hyperspectral nadir imager, 114° FOV, 270-500 nm, 13x24 km footprint for ozone and aerosols
TES	Tropospheric Emission Spectrometer	Reinhard Beer, Mike Gunson, Jet Propulsion Laboratory	Profiles of T, O ₃ , NO ₂ , CO, HNO ₃ , CH ₄ , H ₂ O.	Limb (to 34 km) and nadir IR Fourier transform spectrometer 3.2-15.4μ Nadir footprint 5.3x8.5 km, limb 2.3 km

Science Objectives of the Aura Mission

Aura measurements, when combined with field campaign data, other satellite measurements, and ground based observations, will provide unprecedented insights into atmospheric chemical and dynamical processes.

Is the ozone layer recovering as expected?

Total Ozone Mapping Spectrometer (TOMS) Observations from 1978 show strong secular decrease in column ozone at extra-tropical latitudes. Although the Antarctic ozone hole area growth has slowed significant late winter ozone depletions have now occurred in the Arctic [WMO 2002]. Upper Atmosphere Research Satellite (UARS) data shows a flattening in the stratospheric chlorine concentrations [Anderson et al., 2000]. A decrease in chlorine should lead to recovery of the ozone layer, but this recovery may be altered because of increasing greenhouse gas cooling [e.g. Shindell and Grewe, 2002]. As a result of the uncertainty in stratospheric trace gas trends, temperatures and dynamical feedback processes, current models used to assess the ozone layer do not agree on the timing of the ozone layer recovery [WMO, 2002].

The stratospheric measurements made by Aura will permit a complete assessment of the chemical processes controlling ozone. First, high vertical resolution ozone profiling by MLS and HIRDLS will provide the best information ever on ozone change. Second, five of the major radicals that participate in ozone destruction (ClO, OH, HO₂, BrO and NO₂) will be measured either by HIRDLS or MLS. Third, MLS and HIRDLS also measure the important reservoir gases, HCl, ClONO₂ and HNO₃. Fourth, the Aura instrument payload will make measurements of long-lived source gases including N₂O, H₂O, CH₄, CFC's. Finally, OMI will continue the TOMS/SBUV global column and profile ozone trend measurements.

What are the sources and processes that control tropospheric pollutants?

Tropospheric ozone production occurs when CO, volatile organic compounds (VOCs), and nitrogen oxides are exposed to sunlight. These ozone precursors are directly linked to urban sources, and the atmosphere can transport both ozone and its precursors over large distances. The Aura mission is designed to produce the first global assessment of tropospheric ozone and its precursors, as well as be better able to assess the stratospheric contribution to the ozone budget. The measurements from TES as well as measurements from OMI combined with stratospheric measurements of NO₂ and ozone from HIRDLS and MLS will provide new information on the pollution sources and transport.

What is the quantitative impact of aerosols and upper tropospheric water vapor and ozone in climate change?

One of the sources of uncertainty in climate change comes from our poor understanding of the changing concentration of upper troposphere and lower stratospheric (UT/LS)

constituents [Houghton et al., 1995]. On decadal time scales, climate signals from greenhouse gas changes and changes in reactive constituents are intertwined. Aura's MLS and HIRDLS instruments have been specifically designed to study the UT/LS in unprecedented detail. MLS can make constituent measurements through thin clouds while HIRDLS can scan vertically across the limb over a wide horizontal range through cloud gaps. The issues of climate radiative forcing cannot be solved by Aura alone. Data from Aqua, Cloudsat and CALIPSO will also be needed to address climate issues fully.

Aura Instrument Descriptions

Fig.2 shows the instrument fields of view. MLS will make limb sounds observing forward. OMI and TES will make nadir soundings. HIRDLS and TES will make limb soundings observing backward. The advantage of this instrument configuration is that each of the instruments can observe the same air mass within ~13 minutes.

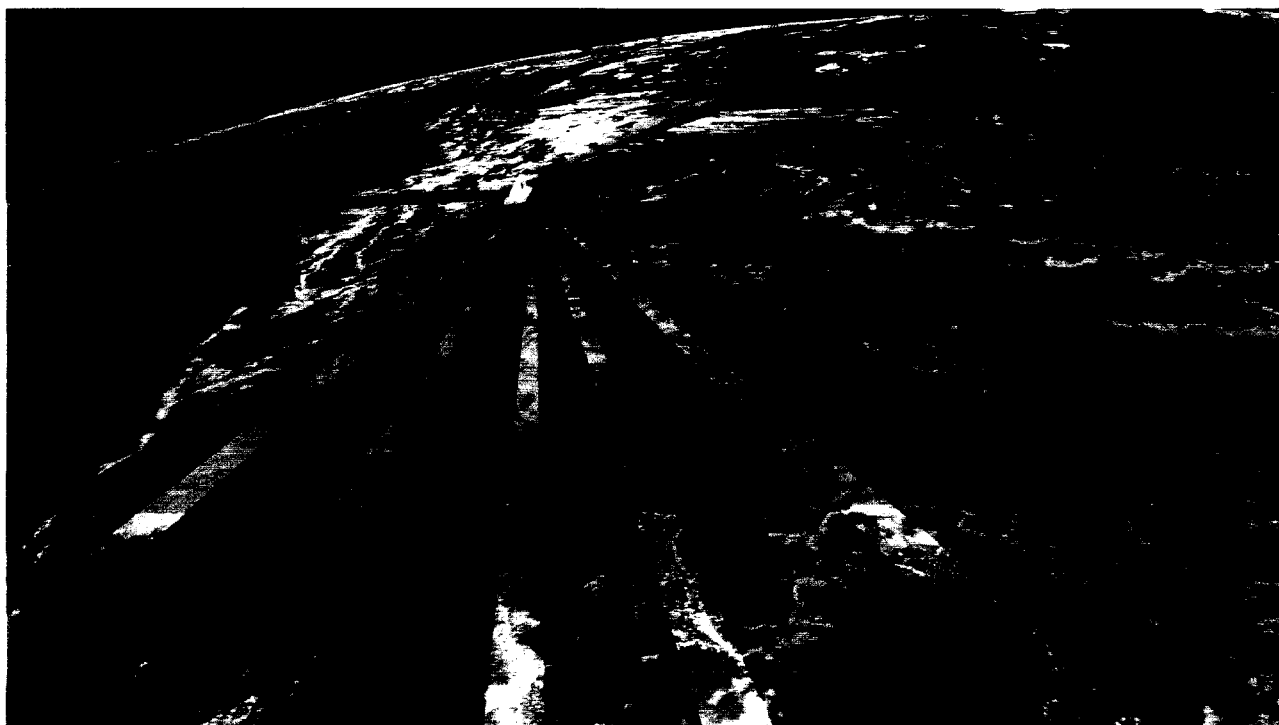


Figure 2. Aura instrument instantaneous fields of view, looking toward the back of the spacecraft. MLS limb measurements, green, OMI nadir measurements, blue swath. TES limb and nadir measurements, red; HIRDLS measurements yellow. Limb sounders scan vertically. (Graphic by Jesse Allen, NASA Earth Observatory)

HIRDLS

HIRDLS is a limb scanning, 6-17 μ m, 26 channel infrared filter radiometer. HIRDLS makes temperature and trace gases observations from the UT/LS to the mesosphere (Table 1) [Gille et al, 2003]. HIRDLS was jointly built by the United Kingdom and the United States. HIRDLS can also detect clouds and thus determine the altitude of polar stratospheric

clouds and tropospheric cloud tops. HIRDLS has higher horizontal resolution than any previous limb sounder through the use of a programmable azimuth scan in conjunction with a rapid elevation scan. Special observing modes can be used in flight to observe geophysical events like volcanic clouds.

MLS

MLS is a 118 GHz-2.5 THz, limb scanning microwave emission spectrometer that measures temperature and constituents from the UT/LS to the mesosphere (Table 1) [Waters et al, 1999]. MLS also has capability of measuring upper tropospheric water vapor in the presence of cirrus. Aura MLS is based on UARS MLS but uses advanced technology to provide new constituent measurements that play important roles in stratospheric chemistry (i.e. HCl, N₂O, OH, HO₂ and BrO). The UARS MLS was able to measure upper tropospheric water vapor [Read et al., 2001] which is essential for understanding climate variability and global warming, and Aura MLS will improve this measurement.

OMI

The OMI instrument is a contribution of the Netherlands' Agency for Aerospace Programs (NIVR) in collaboration with the Finnish Meteorological Institute (FMI) [Levelt et al., 2000]. OMI will continue the TOMS record for total ozone and other atmospheric parameters related to ozone chemistry and aerosols. OMI is a 0.24-0.50 μm , visible-UV 740 band, cross track hyperspectral imager operating in a push-broom mode. OMI will provide global coverage in oneday at 13 x 24 km spatial resolution. A combination of algorithms including the TOMS Version 8, differential optical absorption spectroscopy (DOAS), hyperspectral backscatter ultraviolet retrievals and forward modeling will be used together to generate the various OMI data products [Ahmad et al., 2003].

TES

TES is a 3.2 -15.4 μm , high-resolution infrared-imaging Fourier Transform spectrometer. TES has a spectral resolution of 0.025 cm^{-1} measuring most of the radiatively active molecular species in the Earth's atmosphere [Beer et al., 2001]. TES can make both limb and nadir observations (Table 1). TES target within 45° of the local vertical, or produce regional transects up to 885 km in length without any gaps in coverage. TES will provide global maps of trace gases listed in Table 1. Because TES measures the entire IR spectrum, the potential exists to retrieve a large number of other gases (e.g. ammonia); although the retrieval of these gases will be done in a research mode.

Aura instrument synergy

Two examples of instrument synergy: Because HIRDLS and MLS observe the same air mass within 13 minutes, it will also be possible to better interpret photochemical processes involving constituents measured simultaneously by HIRDLS and MLS such as has been done with UARS data (e.g. Douglass et al. 1995). In addition, HIRDLS and MLS

limb sounding will provide ozone profiles that are nearly simultaneous with the OMI observations. It will then be possible to combine observations from these three instruments to separate the stratospheric component of the total column ozone and thus estimate the tropospheric ozone column. The tropospheric residual can be compared with the TES direct measurement of tropospheric ozone profiles.

Summary

The EOS Aura mission will provide an significantly improved level of constituent measurements. Although there are only four instruments on Aura, the breadth of the their capability combined with the other A-Train measurements will provide a powerful tool to attack future questions concerning the changing atmospheric composition and its impact on climate.

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